CHAPTER 8

DRAINAGE PIPE

8-1. General. A drainage pipe is defined as a structure (other than a bridge) to convey water through or under a runway, roadway, or some other obstruction. Materials for these installations include plain or nonreinforced concrete, reinforced concrete, clay, asbestos-cement, PVC, corrugated steel, corrugated aluminum, and corrugated polyethylene.

8-2. Selection of type of pipe.

a. Material selection. The selection of a suitable construction conduit will be governed by the availability and suitability of pipe materials for local conditions with due consideration of economic factors. Scarcity of materials under mobilization condition may require last minute substitution. The design should be flexible enough to readily accept substitutions. It is desirable to permit alternatives so that bids can be received with Contractor's options for the different types of pipe suitable for a specific installation. Where field conditions dictate the use of one pipe material in preference to others, the reasons will be clearly presented in the design analysis.

b. Design considerations. Several factors should be considered in selecting the type of pipe to be used in construction. The factors include strength under either maximum or minimum cover being provided, pipe bedding and backfill conditions, anticipated loadings, length of pipe sections, ease of installation, resistance to corrosive action by liquids carried or surrounding soil materials, suitability of jointing methods, provisions for expected deflection without adverse effects on the pipe structure or on the joints or overlying materials, and cost of maintenance. It may be necessary to obtain an acceptable pipe installation to meet design requirements by establishing special provisions for several possible materials.

8-3. Selection of n values. Because of the temporary nature (5-year life expectancy) of the installation, "n" should tend toward new pipe values. Sedimentation or paved pipe can affect the coefficient of roughness. Table 8-1 gives the n values for smooth interior pipe of any size, shape, or type and for annular and helical corrugated metal pipe both unpaved and 25 percent paved.

8-4. Restricted use of bituminous-coated pipe. Corrugated-metal pipe with any percentage of bituminous coating will not be installed where fuel spillage, wash rack waste, or solvents can be expected to enter the pipe.

Table 8-1. Roughness Coefficients for Various Pipes

Type of Pipe	n Valve Unpaved	n Valve 25% Paved
Smooth interior*	0.013	0.013
Annular Corrugated Metal		
Corrugation size		
2 + 2/3 by 1/2 inch	0.024	0.021
3 by 1 inch	0.027	0.023
6 by 2 inch	0.028 - 0.033	0.024 - 0.028
9 by 2 + 1/2 inch	0.033	0.028
Helical Corrugated Metal (2 + 2/3 by 1/2 inch corrugations)		
Pipe diameter		
12 - 18 inches	0.011 - 0.014	x
24 - 30 inches	0.016 - 0.018	0.015 - 0.016
36 - 96 inches	0.019 - 0.024	0.017 - 0.021

*Pipes of any size, shape or type including asbestos cement, bituminized fiber, cast iron, clay, PVC, concrete (precast or cast-in-place) or fully paved corrugated pipe.

U.S. Army Corps of Engineers

8-5. Minimum cover.

a. Conduits under pavement. In the design and construction of the drainage system it will be necessary to consider both minimum and maximum earth cover allowable in the underground conduits to be placed under both flexible and rigid pavements as well as beneath unsurfaced roads, airfields, and medium-duty landing-mat-surfaced fields. Underground conduits are subject to two principal types of loads: dead loads caused by embankment or trench backfill plus superimposed stationary surface loads, uniform or concentrated and live or moving loads, including impact. Live loads assume increasing importance with decreasing fill height. This section refers to minimum cover considerations only.

b. Capacity. Drainage systems should be designed in order to provide an ultimate capacity sufficient to serve the planned pavement configuration. Additions to, or replacement of, drainage lines following initial construction is both costly and disrupting to traffic.

c. Construction cover. It should be noted that minimum conduit cover requirements are not always adequate during construction. When construction equipment, which may be heavier than live loads for which the conduit has been designed, is operated over or near an already in-place underground conduit, it is the responsibility of the Contractor to provide any additional cover during construction to avoid damage to the conduit.

d. Anticipated loads. For minimum cover design, the maximum anticipated loads (H20-44, Cooper E60, 15-kip and 25-kip single wheel, 100-kip twin wheel, 265-kip twin-twin [B-52] and 360-kip 12-wheel [C-5A] assembly loads referred to as single, dual, dual-tandem and multiple wheel) have been considered. The necessary minimum cover in certain instances may determine pipe grades. A safe minimum cover design requires consideration of a number of factors including selection of conduit material, construction conditions and specifications, selection of pavement design, selection of backfill material and compaction, and the method of bedding underground conduits. Emphasis on these factors must be carried from the design stage through the development of final plans and specifications.

e. Recommended cover. Tables 8-2 and 8-3 identify the recommended minimum cover requirements for storm drains and culverts. Minimum cover requirements have been formulated for: asbestos-cement pipe, corrugated-steel pipe, reinforced concrete culverts and storm drains, standard strength clay and nonreinforced concrete pipe, extra strength clay and nonreinforced concrete pipe and PVC pipe. The cover depths recommended are valid for average bedding and backfill conditions. Deviations from these conditions may result in significant changes in the minimum cover requirements.

Table 8-2. Minimum Pipe Cover Requirements for Airfields and Heliports
(Cover in Feet for Indicated Wall Thickness or Pipe Class)

Pipe diameter in.	For Corrugated Steel (2 + 2/3-in. Corrugations) 0.052 in.	0.064 in.	0.079 in.	0.109 in.	0.138 in.	0.168 in.	Reinforced-Concrete Culverts and Storm Drains Class I 1200 D	Class II 1500 D	Class III 2000 D	Class IV 3000 D	Class V 3750 D	Asbestos-Cement Pipe Class 1500	Class 2500	Class 3300	Class 4000	Class 5000	Clay and Non-Reinforced Concrete Pipe Standard Strength	Extra Strength	PVC Pipe Sch. 40	Pipe diameter in.
15,000-lb SINGLE-WHEEL LOAD																				
6	1.0	1.0	-	-	-	-	-	2.5	2.0	1.5	1.0	1.5	1.0	1.0	-	-	2.0	1.5	2.5	6
12	1.0	1.0	1.0	-	-	-	-	2.5	2.0	1.5	1.0	2.5	2.0	1.5	1.0	1.0	2.5	2.0	3.5	12
24	1.0	1.0	1.0	1.0	1.0	-	-	2.5	2.0	1.5	1.0	-	3.5	2.0	2.0	1.5	3.5	2.0	*3,5	24
36	1.0	1.0	1.0	1.0	1.0	1.0	-	2.5	2.0	1.5	1.0	-	-	-	2.5	2.0	2.5	2.0	(* 15.inch	36
48	-	1.0	1.0	1.0	1.0	1.0	2.5	2.0	2.0	1.5	1.0								diameter	48
60	-	-	1.0	1.0	1.0	1.0	2.5	2.0	2.0	1.5	1.0								pipe)	60
72	-	-	-	1.0	1.0	1.0	2.5	2.0	2.0	1.5	-									72
84	-	-	-	-	1.0	1.0	2.5	2.0	2.0	-	-									84
96	-	-	-	-	-	1.0	2.5	2.0	2.0	-	-									96
25,000-lb SINGLE-WHEEL LOAD																				
6	1.0	1.0	-	-	-	-	-	3.5	3.0	2.0	1.5	2.0	1.5	1.0	-	-	2.5	1.5	3.5	6
12	1.0	1.0	1.0	-	-	-	-	3.5	2.5	2.0	1.5	3.5	2.5	2.0	1.5	1.5	3.5	2.5	5.0	12
24	1.0	1.0	1.0	1.0	1.0	-	-	3.0	2.5	2.0	1.5	-	4.5	3.0	2.5	2.0	4.5	2.5	*5.0	24
36	1.0	1.0	1.0	1.0	1.0	1.0	-	3.0	2.5	2.0	1.5	-	-	-	3.0	2.5	3.0	2.5		36
48	-	1.0	1.0	1.0	1.0	1.0	3.5	3.0	2.5	2.0	1.5									48
60	-	-	1.0	1.0	1.0	1.0	3.5	2.5	2.0	2.0	1.5									60
72	-	-	-	1.0	1.0	1.0	3.0	2.5	2.0	2.0	-									72
84	-	-	-	-	1.0	1.0	3.0	2.5	2.0	-	-									84
96	-	-	-	-	-	1.0	3.0	2.5	2.0	-	-									96
C-5A																				
6	1.0	1.0	-	-	-	-	-	-	-	6.5	2.0									6
12	1.0	1.0	1.0	-	-	-	-	-	-	6.0	2.0									12
24	1.0	1.0	1.0	1.0	-	-	-	-	-	5.0	2.0									24
36	1.0	1.0	1.0	1.0	1.0	1.0	-	-	-	4.5	2.0									36
48	-	1.0	1.0	1.0	1.0	1.0	-	-	-	4.5	2.0			Not Available			Not Available		Not Available	48
60	-	-	1.0	1.5	1.0	1.0	-	-	-	4.5	2.0									60
72	-	-	-	-	1.0	1.0	-	-	-	4.0	2.0									72
84	-	-	-	-	1.0	1.0	-	-	8.0	4.0	2.0									84
96	-	-	-	-	-	1.5														96
100,000-lb TWIN-WHEEL ASSEMBLY LOAD																				
6	1.0	1.0	-	-	-	-	-	-	-	5.0	4.0	5.0	3.0	2.5	-	-	8.0	3.5	6.5	6
12	1.0	1.0	1.0	-	-	-	-	-	7.5	4.5	3.5	-	6.0	4.5	3.5	3.0	-	6.0	7.0	12
24	1.0	1.0	1.0	1.0	1.0	-	-	-	7.0	4.0	3.0	-	-	-	7.5	5.5	-	6.5	*7.0	24
36	1.5	1.0	1.0	1.0	1.0	1.0	-	-	6.0	4.0	3.0	-	-	-	-	-	-	7.0		36
48	-	1.5	1.0	1.0	1.0	1.0	-	-	6.0	4.0	3.0									48
60	-	-	1.5	1.0	1.0	1.0	-	-	5.5	3.5	3.0									60
72	-	-	-	1.5	1.5	1.0	-	-	5.5	3.5	-									72
84	-	-	-	-	2.0	1.5	-	-	5.5	-	-									84
96	-	-	-	-	-	2.5	-	-	5.0	-	-									96
265,000-lb TWIN-WHEEL ASSEMBLY LOAD																				
6	1.0	1.0	-	-	-	-	-	-	-	9.5	6.5	8.0	5.0	3.5	-	-	-	6.0	9.0	6
12	1.0	1.0	1.0	-	-	-	-	-	-	8.0	6.0	-	-	8.0	6.0	5.0	-	-	10.0	12
24	1.0	1.0	1.0	1.0	1.0	-	-	-	-	7.5	6.0	-	-	-	-	-	-	-	*10.0	24
36	1.5	1.5	1.0	1.0	1.0	1.0	-	-	-	7.0	5.5	-	-	-	-	-	-	-		36
48	-	2.0	1.5	1.0	1.0	1.0	-	-	-	6.5	5.0									
60	-	-	-	1.5	1.0	1.0	-	-	-	6.0	5.0									
72	-	-	-	2.0	1.5	1.0	-	-	-	6.0	-									
84	-	-	-	-	2.5	1.5														
96	-	-	-	-	-	3.5														

NOTES:

(1) Except where individual pipe installation designs are made, cover for pipe beneath runways, taxiways, aprons, or similar traffic areas will be provided in accordance with this table for flexible pavement or unpaved surfaces. See note 8 for pipe underlying rigid pavements.

(2) Cover for pipe in airfield non-traffic areas will be designed for 15,000-lb. single-wheel load.

(3) Cover depths are measured from top of flexible pavement or unsurfaced areas to top of pipe, except top of pipe is not to be above bottom subbase material.

(4) Pipe produced by certain manufacturers exceeds strength requirements established by indicated standards. When additional strength is proved, the minimum cover may be reduced accordingly.

(5) At present, minimum cover for aluminum alloy and polyethylene corrugated pipe installed beneath flexible pavements is not available. In the absence of other criteria, the following minimum requirements will be followed:

15,000-lb. single wheel	Use values shown for corrugated steel pipe
25,00-lb. single wheel	Increase cover depths shown for corrugated steel pipe by 0.5 feet
C-5A	Same as above, except increase cover depth 1.0 feet
265,000-lb. twin-twin assembly	Same as above, except increase cover depth 1.5 feet

(6) "D" loads listed for the various classes of reinforced-concrete pipe are the minimum required 3-edge test loads to produce ultimate failure, in pounds per linear foot of internal pipe diameter.

(7) The class designation number for asbestos-cement pipe is the minimum required 3-edge test load to produce ultimate failure in pounds per linear foot. It is independent of pipe diameter. An equivalent to the D load can be obtained by dividing the number in the class designation by the internal pipe diameter in feet.

(8) Pipe placed under airfield rigid pavements will have a minimum cover, measured from the bottom of the slab, as follows:

Pipe Sizes, in.	15,000-lb. Single-Wheel	25,000-lb. Single-Wheel	C-5A	100,000-lb. Twin Assembly	265,000-lb. Twin-Twin Assembly
6-60	0.5	0.5	1.0	1.0	1.0
66-180	1.0	1.0	1.5	1.5	1.5

Table 8-3. Minimum Pipe Cover Requirements for Roads and Railroads (Feet)

Pipe Material	Diameter of Pipe (inches)												
	8	10	12	15	18	21	24	30	36	48	60	72	84
Corrugated Steel Pipe (2-2/3 x 1/2)													
Flexible Pavement	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.5	1.5
Rigid Pavement	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	1.0	1.0
Railroad	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.5	1.5
Reinforced Concrete													
Flexible Pavement	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.5	3.0	3.5
Rigid Pavement	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	2.0	2.0	2.5
Railroad	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.5	3.0	3.5
Asbestos-Cement													
Flexible Pavement	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0			
Rigid Pavement	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0			
Railroad	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0			
Non-Reinforced Concrete													
Flexible Pavement	2.5	2.5	3.0	3.0	3.0	3.0	3.0	3.0	3.0				
Rigid Pavement	2.0	2.0	2.5	2.5	2.5	2.5	2.5	2.5	2.5				
Railroad	2.5	2.5	3.0	3.0	3.0	3.0	3.0	3.0	3.0				
Clay (Std. Str.)													
Flexible Pavement	2.5	2.5	3.0	3.0	3.0	3.0	3.0	3.0	3.0				
Rigid Pavement	2.0	2.0	2.5	2.5	2.5	2.5	2.5	2.5	2.5				
Railroad	2.5	2.5	3.0	3.0	3.0	3.0	3.0	3.0	3.0				
PVC and ASB Sch 40													
Flexible Pavement		As Recommended											
Rigid Pavement		by the											
Railroad		Manufacturer											
Corrugated Polyethylene													
Flexible Pavement		As Recommended											
Rigid Pavement		by the											
Railroad		Manufacturer											

NOTES:

(1) Table will be used for typical installations with dead load plus either Cooper E-60 railway or H20-44 highway loading.

(2) Minimum cover for pipe will be measured from the bottom of the railway tie to the top of pipe. Minimum cover for pipe placed under rigid pavements will be measured from the bottom of the slab to top of pipe. When pipe is to be placed beneath flexible pavements, minimum cover for pipe will be measured from the top of pavement surface to top of pipe; however, in no case is the top of pipe to be above the bottom of subbase.

(3) Minimum wall thickness for corrugated steel pipe under rigid or flexible pavements for pipe diameters less than 36 inches, 16 gage; 36 and 48 inches, 12 gage; over 48 inches, 10 gage, for pipe under railroads, less than 36 inches, 14 gage; 36 and 48 inches, 10 gage; over 48 inches, 8 gage.

f. Embedment. Figures 8-1, 8-2, 8-3, and 8-4 indicate the three main classes of acceptable rigid conduit bedding, the free-body conduit diagrams, load factors and class of bedding, and beddings for positive projecting conduits, respectively. Figure 8-5 is a schematic representation of the subdivision of classes of conduit installation which influences loads on underground conduits.

8-6. Frost condition considerations.

a. Frostheave. The detrimental effects of heaving of frost-susceptible soils around and under storm drains and culverts is a principal consideration in the design of drainage systems in seasonal frost areas. In such areas, freezing of water within the drainage system, except icing at inlets, is of secondary importance provided the hydraulic design assures minimum velocity flow. Drains, culverts, and other utilities under pavements on frost-susceptible subgrades are frequently locations of detrimental differential surface heaving. Heaving causes pavement distress and loss of smoothness due to abrupt differences in the rate and magnitude of heave of the frozen materials. Heaving of frost-susceptible soils under drains and culverts can also result in pipe displacement with consequent loss of alinement, joint failures and, in extreme cases, pipe breakage. Placing drains and culverts beneath pavements should be avoided whenever possible. When this is unavoidable, the pipes should be installed before the base course is placed in order to obtain maximum uniformity.

b. Base-course excavation. The practice of excavating through base courses to lay drains, pipes, and other conduits is unsatisfactory since it is almost impossible to attain uniformity between the compacted trench backfill and the adjacent material. Special design considerations for frost conditions and recommended minimum depth of cover for protection of storm drains and culverts in seasonal frost areas are given in table 8-4.

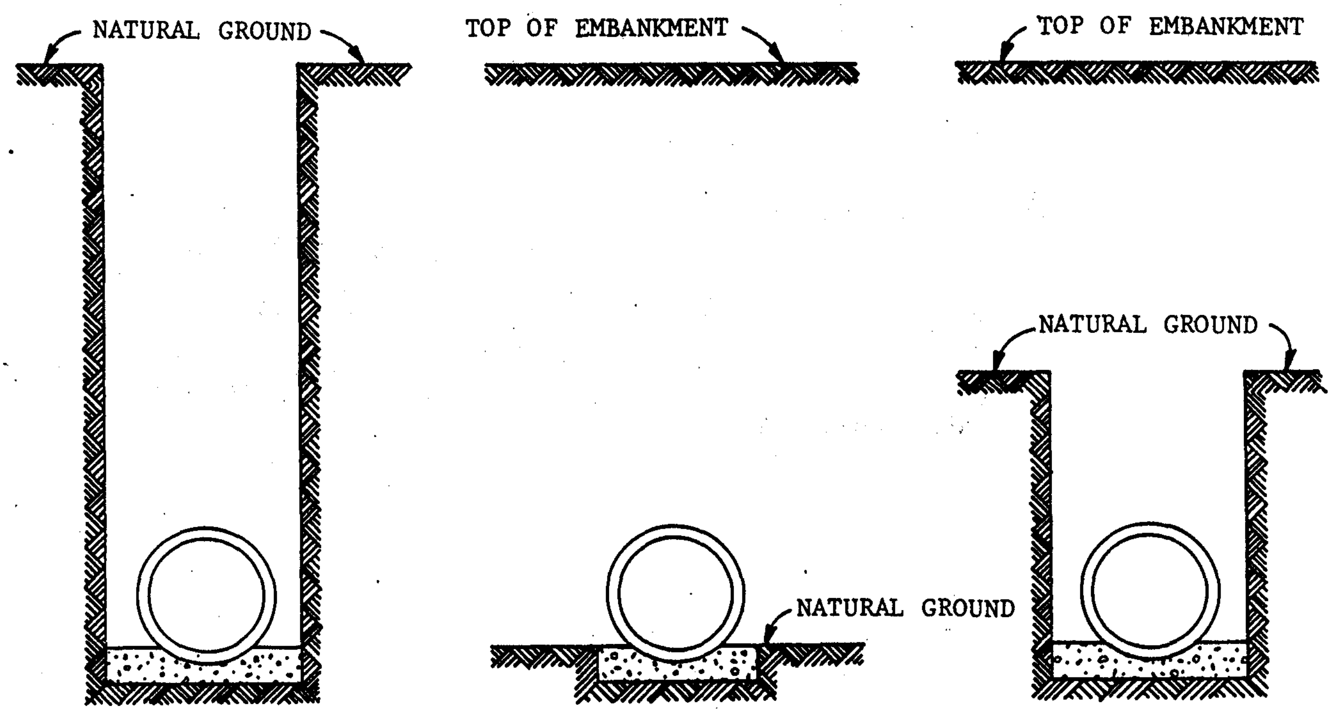
c. Design considerations. The following design criteria should be considered for installations located in seasonal frost areas.

(1) Cover requirement for traffic loads will govern when such depth exceeds that necessary for frost protection.

(2) Sufficient granular backfill will be placed beneath inlets and outlets to restrict frost penetration to nonheaving materials.

(3) Design of short pipes with exposed ends, such as culverts under roads, will consider local icing experience. If necessary, extra size pipe will be provided to compensate for icing.

(4) Depth of frost penetration in well drained, granular, non-frost-susceptible soil beneath pavements kept free of snow and ice can be determined from figures 8-6 or 8-7. For other soils and/or



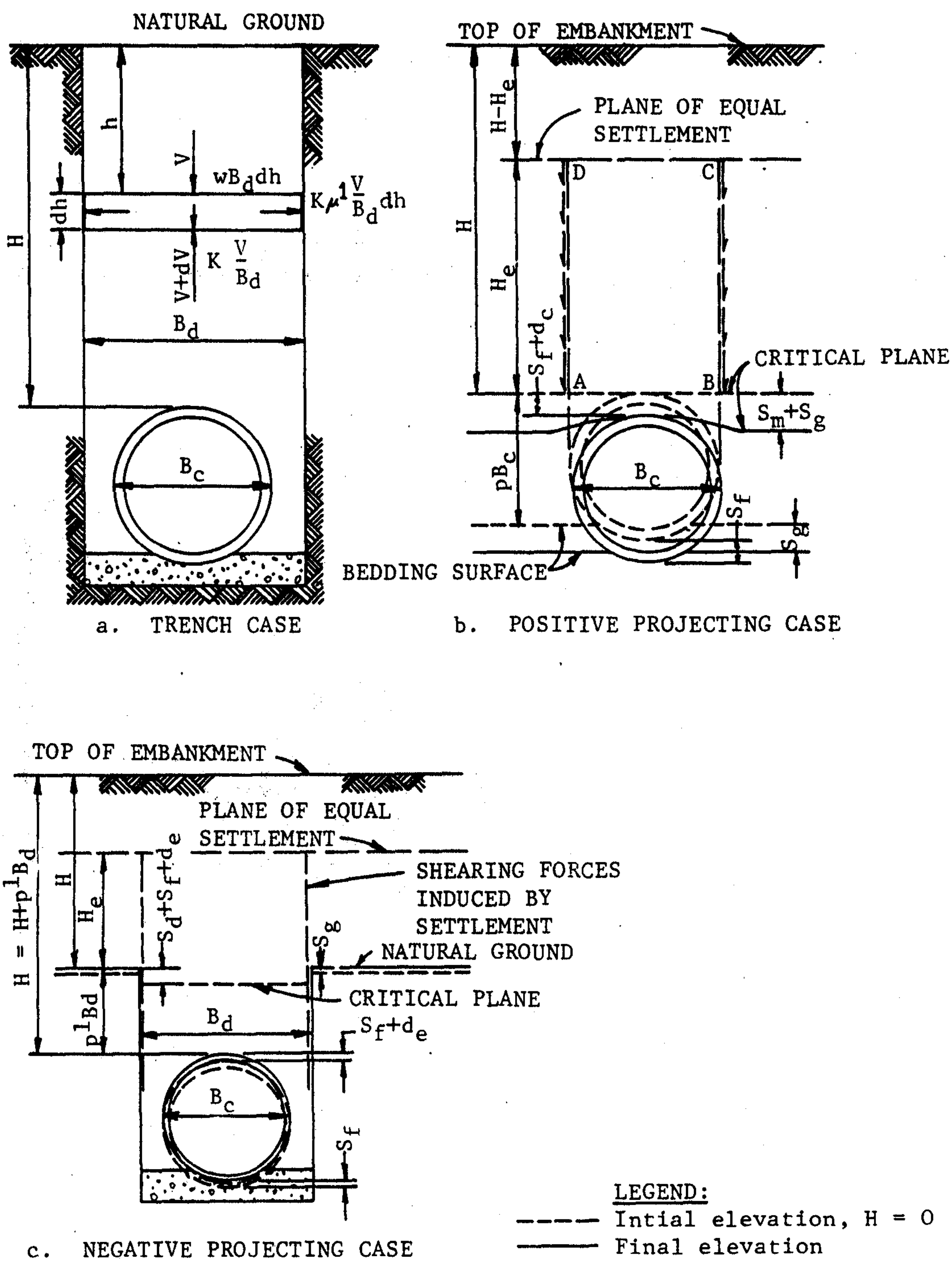
a. TRENCH CONDUIT

b. POSITIVE PROJECTING CONDUIT

c. NEGATIVE PROJECTING CONDUIT

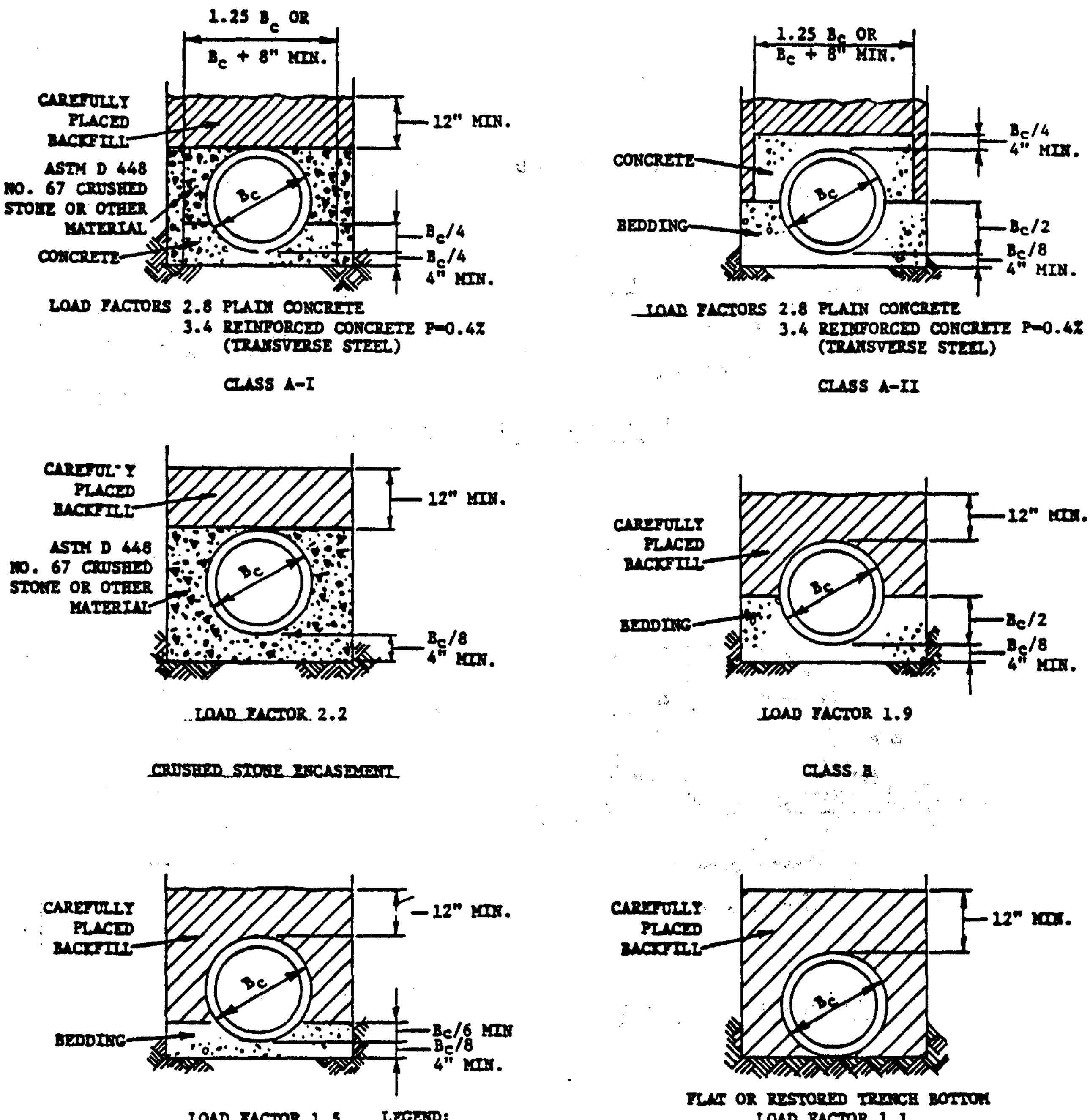
U.S. Army Corps of Engineers

FIGURE 8-1. THREE MAIN CLASSES OF CONDUITS



U.S. Army Corps of Engineers

FIGURE 8-2. FREE-BODY CONDUIT DIAGRAMS

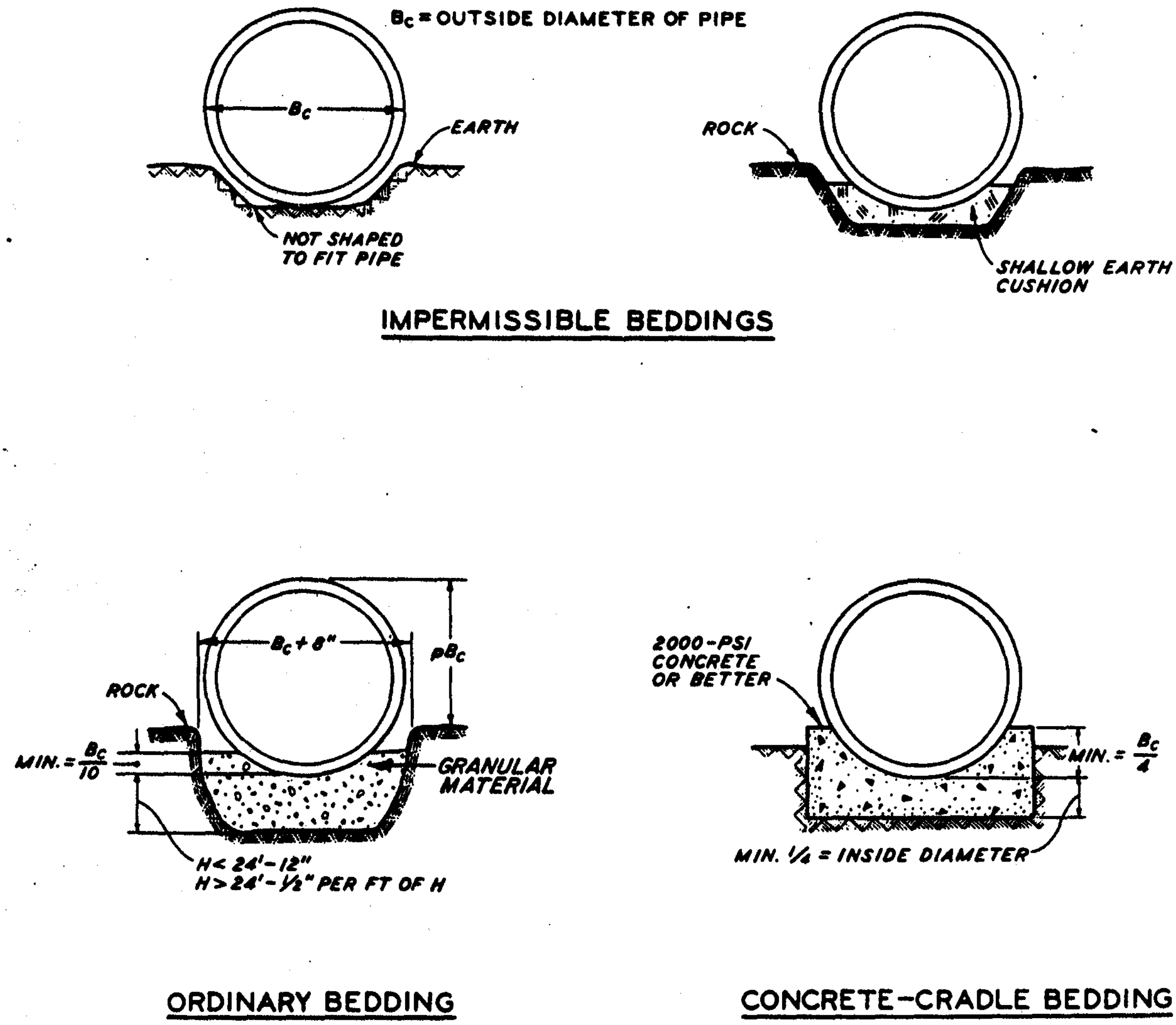


LEGEND:
B_c = Outside diameter of pipe
H = Backfill cover above top of pipe
D = Inside diameter of pipe
d = Depth of bedding material below pipe
A = Area of transverse steel in the cradle of arch expressed as 3 percent of the area of concrete at the invert or crown

NOTE: For rock or other incompressible material, the trench should be overexcavated a minimum of 6 inches and refilled with granular material.

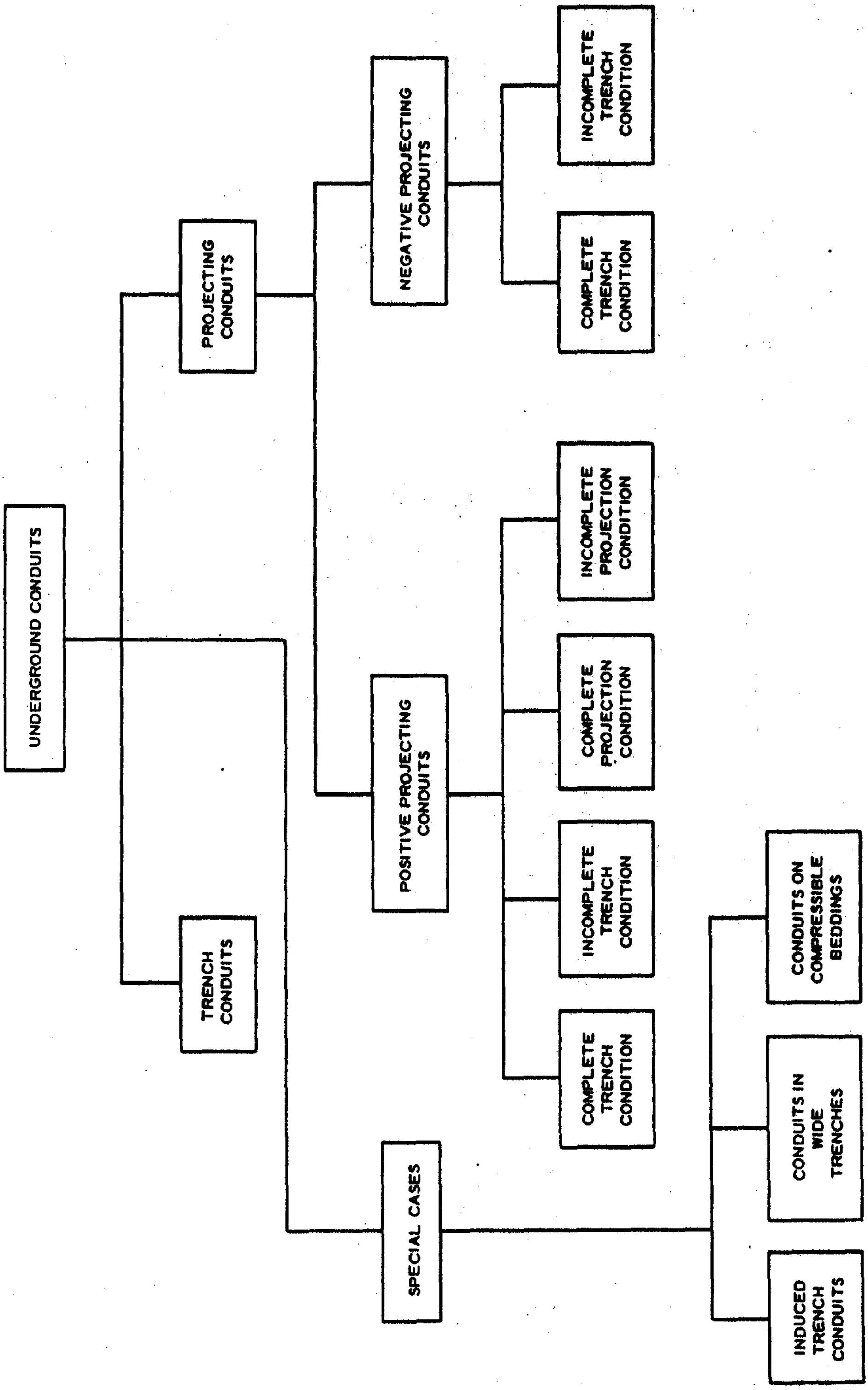
CLAY PIPE ENGINEERING MANUAL BY NATIONAL CLAY PIPE INSTITUTE, 1982, P. 52-53.

FIGURE 8-3. **LOAD FACTORS AND CLASS OF BEDDING**



U.S. Army Corps of Engineers

FIGURE 8-4. BEDDING FOR POSITIVE PROJECTING CONDUITS



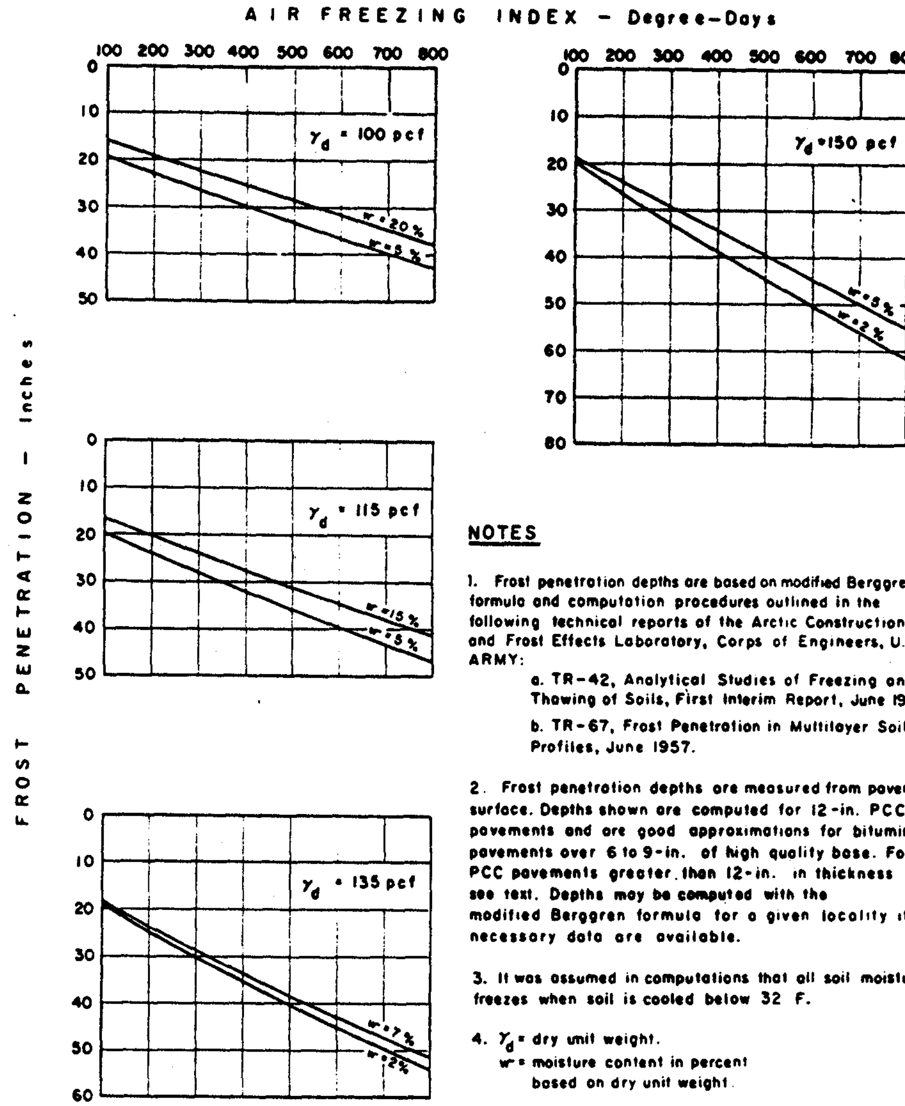
U.S. Army Corps of Engineers

FIGURE 8-5. INSTALLATION CONDITIONS WHICH INFLUENCE LOADS ON UNDERGROUND CONDUITS

Table 8-4 Minimum Required Depth of Cover Protection of Storm Drains and Culverts in Seasonal Frost Areas

Position of highest ground water table	Nonfrost susceptible subgrade		Frost susceptible subgrade	
	To prevent heave	To prevent freezing of water in pipe	To prevent heave	To prevent freezing of water in pipe
Less than 5 ft. below maximum depth of frost penetration	No special measures required	Place invert of pipe at or below depth of maximum frost penetration	For pipe diameters smaller than 18 in. place centerline of pipe at or below depth of maximum frost penetration. For pipe diameters 18 in. or larger, place centerline of pipe 1/3 diameter below depth of maximum frost penetration or place centerline of pipe at a depth of maximum frost penetration and backfill around pipe with highly free draining, non-frost-susceptible material.	Place invert of pipe at or below depth of maximum frost penetration
5 ft. or more below maximum depth of frost penetration	No special measures required	Place invert of pipe at or below depth of maximum frost penetration	Place centerline of pipe at at or below depth of maximum frost penetration	Place invert of pipe at or below depth of maximum frost penetration

U.S. Army Corps of Engineers

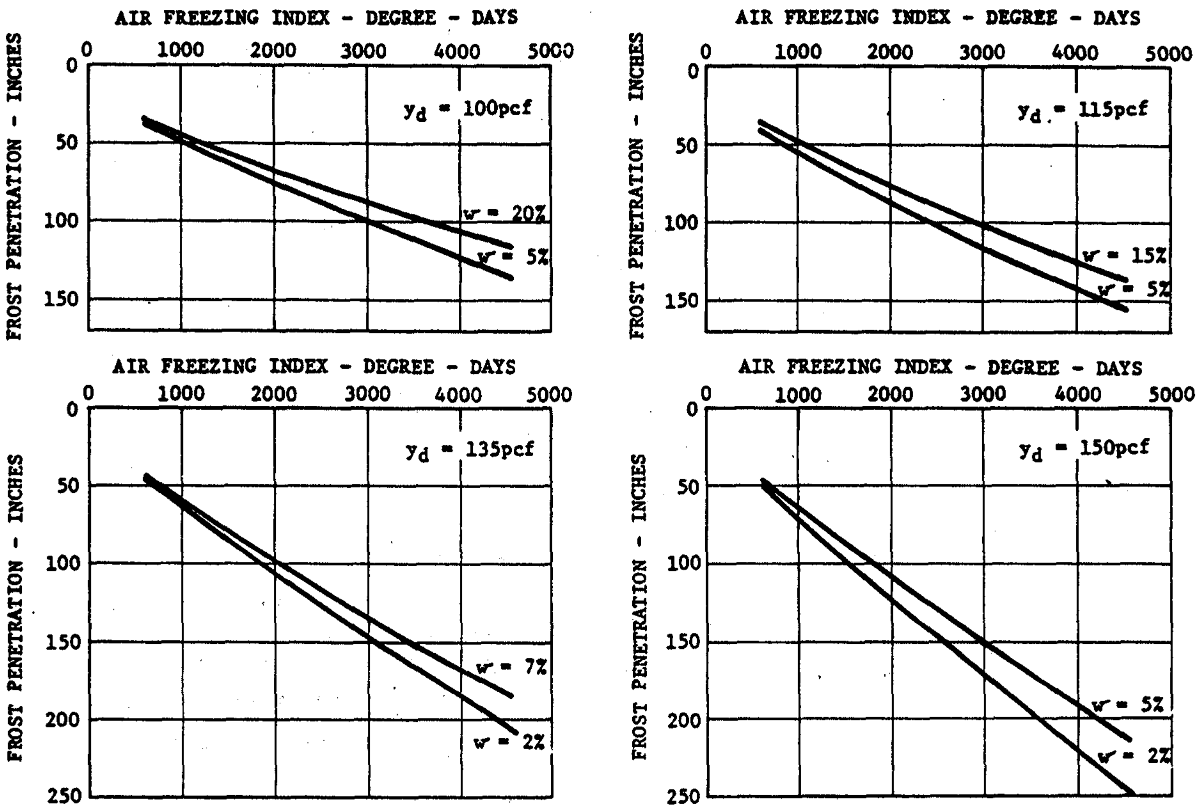


NOTES

1. Frost penetration depths are based on modified Berggren formula and computation procedures outlined in the following technical reports of the Arctic Construction and Frost Effects Laboratory, Corps of Engineers, U.S. ARMY:
   a. TR-42, Analytical Studies of Freezing and Thawing of Soils, First Interim Report, June 1953.
   b. TR-67, Frost Penetration in Multilayer Soil Profiles, June 1957.
2. Frost penetration depths are measured from pavement surface. Depths shown are computed for 12-in. PCC pavements and are good approximations for bituminous pavements over 6 to 9-in. of high quality base. For PCC pavements greater than 12-in. in thickness see text. Depths may be computed with the modified Berggren formula for a given locality if necessary data are available.
3. It was assumed in computations that all soil moisture freezes when soil is cooled below 32 F.
4. γ_d = dry unit weight.
   w = moisture content in percent based on dry unit weight.

U.S. Army Corps of Engineers

FIGURE 8-6. RELATIONSHIPS BETWEEN AIR FREEZING INDEX AND FROST PENETRATION INTO GRANULAR, NONFROST-SUSCEPTIBLE SOIL BENEATH PAVEMENTS KEPT FREE OF SNOW AND ICE FOR FREEZING INDEXES BELOW 800



SEE NOTES ON FIGURE 8-6

U.S. Army Corps of Engineers

FIGURE 8-7. RELATIONSHIPS BETWEEN AIR FREEZING INDEX AND FROST PENETRATION INTO GRANULAR, NONFROST-SUSCEPTIBLE SOIL BENEATH PAVEMENTS KEPT FREE OF SNOW AND ICE subsurface conditions, frost penetrations should be determined using conservative surface condition assumption and standard methods. Table 8-5 lists frost penetration for various locations and figure 8-8 indicates areas of varying frost penetrations in the continental United States. In all cases, estimates of frost penetrations should be confirmed by the U.S. Weather Bureau from data gathered at the nearest station to the proposed site. Frost penetrations are to be based on the design freezing index for the coldest winter in the past 10 years.

(5) Under traffic areas and particularly where frost condition pavement design is based on reduced subgrade strength gradual transitions between frost-susceptible subgrade materials and nonfrost-susceptible trench backfill will be provided within the depth of frost penetration to prevent detrimental differential surface heave.

8-7. Infiltration of fine soils through drainage pipe joints.

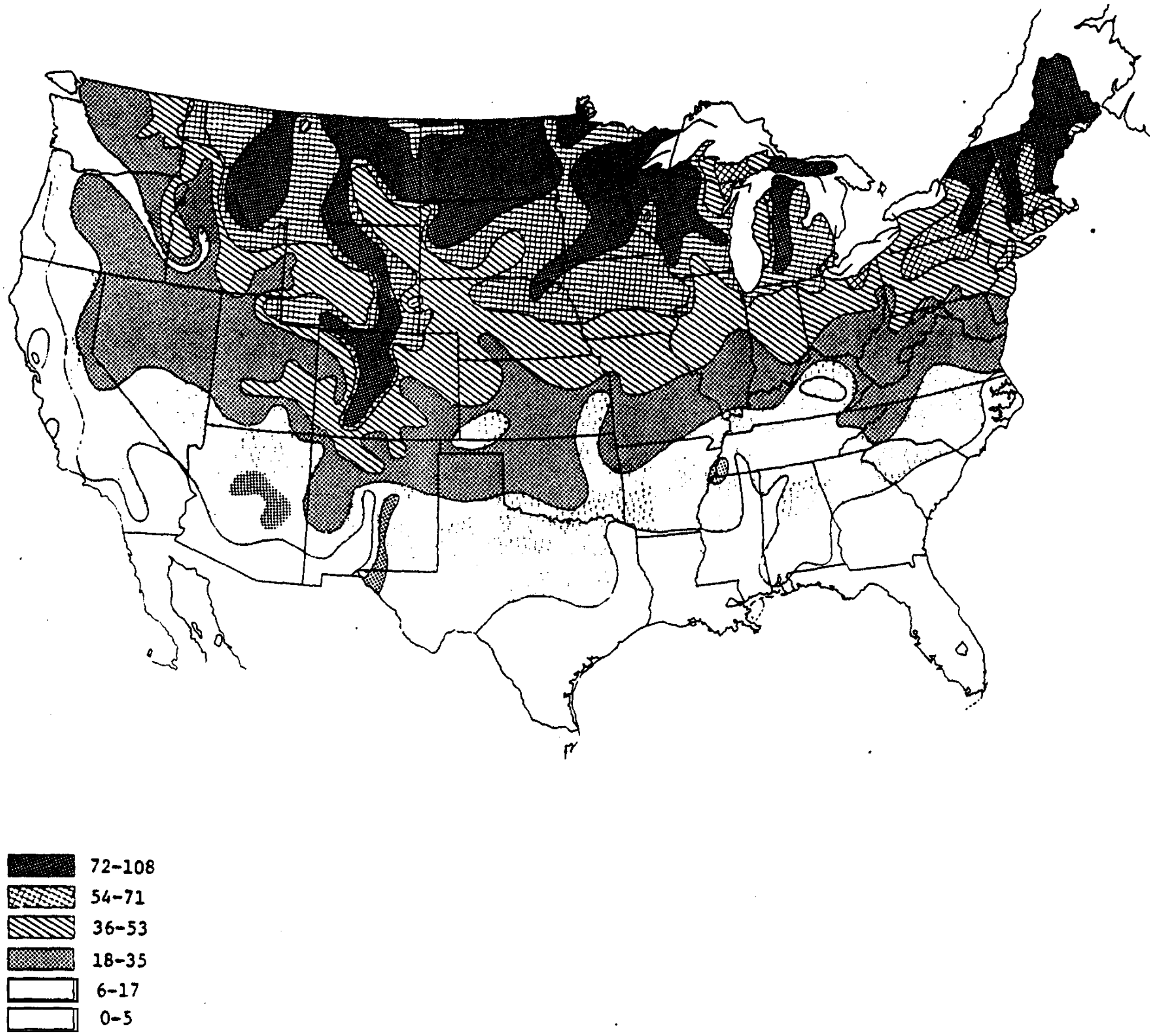
a. Broken back culverts. Infiltration of fine-grained soils into drainage pipelines through joint openings is one of the major causes of ineffective drainage facilities. This is particularly a problem along pipes on relatively steep slopes such as those encountered with broken back culverts or stilling wells. Infiltration is not confined to noncohesive soils. Dispersive soils have a tendency to slake and flow into drainage lines.

b. High water table. Infiltration, prevalent when the water table is at or above the pipeline, occurs in joints of rigid pipelines and in joints and seams of flexible pipe, unless these are made watertight. Watertight jointing is especially needed in culverts and storm drains placed on steep slopes to prevent infiltration and/or leakage and piping that normally results in the progressive erosion of the embankments and loss of downstream energy dissipators and pipe sections.

c. Steep slopes. Culverts and storm drains placed on steep slopes should be sufficiently large and be properly vented so that full pipe flow can never occur in order to maintain the hydraulic gradient above the pipe invert but below crown of the pipe and thereby reduce the tendency for infiltration of soil and water through joints. Pipes on steep slopes may tend to prime and flow full periodically due to entrance or outlet condition effects until the hydraulic or pressure gradient is lowered sufficiently to cause venting or loss of prime at either the inlet or outlet. The alternate increase and reduction of pressure relative to atmospheric pressure is considered to be a primary cause of severe piping and infiltration. It is recommended that a vertical riser be provided upstream of or at the change in slope to provide sufficient venting for establishment of partial flow and stabilization of the pressure gradient in the portion of pipe on the

Table 8-5. Estimated Frost Penetration for Selected Locations

Location	Depth (Inches)
ALABAMA	
Brookley AFB	6
Maxwell AFB	9
Montgomery	6
ARIZONA	
Davis Monthan AFB	5
Luke AFB	7
Phoenix	7
ARKANSAS	
Little Rock AFB	12
CALIFORNIA	
Castle AFB	5
Hamilton AFB	5
March AFB	5
Travis AFB	5
Vandenberg AFB	5
San Diego	0
San Francisco	5
Oakland	5
Mare Island	5
Sacramento	5
COLORADO	
Lowry AFB	60
Denver	60
CONNECTICUT	
New London	35
New Haven	35
DELAWARE	
Dover AFB	20
FLORIDA	
Eglin AFB	5
Homestead AFB	0
MacDill AFB	2
Patrick AFB	2
Jacksonville	2
Key West	0
Pensacola	2
GEORGIA	
Hunter AFB	5
Robins AFB	5
Turner AFB	5
Atlanta	7
Savannah	3
Macon	5
IDAHO	
Mountain Home AFB	40
ILLINOIS	
Chanute AFB	35
Scott AFB	35
Chicago	40
INDIANA	
Fort Wayne	40
Indianapolis	30
IOWA	
Sioux City	54
KANSAS	
Forbes AFB	30
Schilling AFB	24
KENTUCKY	
Lexington	18
Louisville	18
LOUISIANA	
Barksdale AFB	5
Chennault AFB	4
New Orleans	2
MAINE	
Dow AFB	75
Loring AFB	75
Portland	65
Bangor	72
MARYLAND	
Andrews AFB	25
Baltimore	22
MASSACHUSETTS	
L.G. Hanscom Field	50
Otis AFB	50
Westover AFB	70
Boston	50
Springfield	70
MICHIGAN	
Kinchelow AFB	65
Selfridge AFB	50
Detroit	50
MINNESOTA	
Minn-St. Paul IAP	75
Minneapolis	75
Duluth	75
MISSISSIPPI	
Jackson	3
MISSOURI	
Kansas City	28
St. Louis	27
MONTANA	
Malmstrom AFB	75
NEBRASKA	
Offutt AFB	55
Omaha	55
NEVADA	
Nellis AFB	8
Stead AFB	23
Fallon	12
Hawthorne	30
Reno	23
NEW HAMPSHIRE	
Pease AFB	60
Portsmouth	60
NEW JERSEY	
McGuire AFB	30
Atlantic City	20
Bayonne	30
NEW MEXICO	
Cannon AFB	15
Holloman AFB	20
Walker AFB	15
Albuquerque	17
NEW YORK	
Griffis AFB	50
Plattsburg AFB	70
Stewart AFB	45
Buffalo	35
Albany	54
New York	40
Syracuse	56
NORTH CAROLINA	
Pope AFB	9
Charlotte	8
Wilmington	5
NORTH DAKOTA	
Grand Forks AFB	85
Minot	80
OHIO	
Wright-Patterson AFB	40
Columbus	40
Cincinnati	20
OKLAHOMA	
Tinker AFB	20
OREGON	
Portland Int. Apt.	6
Portland	6
PENNSYLVANIA	
Olmsted AFB	35
Harrisburg	30
Pittsburgh	38
Philadelphia	30
RHODE ISLAND	
Providence	45
SOUTH CAROLINA	
Shaw AFB	6
Charleston	3
SOUTH DAKOTA	
Ellsworth AFB	55
TENNESSEE	
Sewart AFB	10
Memphis	10
TEXAS	
Amarillo AFB	20
Bergstrom AFB	4
Biggs AFB	6
Carswell AFB	12
Dyess AFB	10
Ellington AFB	3
Kelly AFB	4
TEXAS (Cont.)	
Reese AFB	15
Sheppard AFB	15
Corpus Christi	2
El Paso	6
Fort Worth	10
Galveston	3
Houston	3
San Antonio	4
Amarillo	20
UTAH	
Hill AFB	35
Salt Lake City	35
VERMONT	
Burlington	72
VIRGINIA	
Langley AFB	6
Newport News	10
Norfolk	10
Richmond	14
WASHINGTON	
Fairchild AFB	65
Larson AFB	35
McChord AFB	10
Bremerton	9
Seattle	8
Spokane	30
Pasco	25
Tacoma	8
WEST VIRGINIA	
Charleston	30
WISCONSIN	
Truax Field	50
Milwaukee	54
Green Bay	54
WYOMING	
Francis E. Warren AFB	70
WASHINGTON, D.C.	20



MAXIMUM DEPTH OF FROST PENETRATION IN INCHES

THE DATA FOR THIS CHART WERE PREPARED BY THE U. S. WEATHER BUREAU IN 1938 AND PUBLISHED BY "HEATING AND VENTILATING." IT IS THE BEST INFORMATION ON THE SUBJECT AVAILABLE AT PRESENT. BOTH VARIABLE-RECORD OBSERVATIONS AND ESTIMATIONS OF MAXIMUM FROST PENETRATIONS WERE USED, RESULTING IN A HIGHLY-DETAILED PRESENTATION THAT MAY IMPLY A RELIABILITY BEYOND THAT ORIGINALLY INTENDED.

FIGURE 8-8. MAXIMUM DEPTH OF FROST PENETRATION steep slope. The riser may also be equipped with an inlet and used simultaneously to collect runoff from a berm or adjacent area.

d. Flexible joint material. Infiltration of backfill and subgrade material can be controlled by watertight flexible joint materials in rigid pipe and with watertight coupling bands in flexible pipe. Successful flexible watertight joints have been obtained in rigid pipelines with rubber gaskets installed in close-tolerance tongue-and-groove joints and factory-installed plastic gaskets installed on bell-and-spigot pipe. Bell-and-spigot joints calked with oakum or other similar rope-type calking materials and sealed with a hot-poured joint compound have also been successful. Metal pipe seams may require welding, and the rivet heads may have to be ground to lessen interference with gaskets. There are several kinds of connecting bands which are adequate both hydraulically and structurally for joining corrugated metal pipes on steep slopes. The results of laboratory research concerning soil infiltration through pipe joints and the effectiveness of gasketing tapes for waterproofing joints and seams are available.

e. Flexible joint installation. Installation of flexible watertight joints will conform closely to manufacturer's recommendations, and a conclusive infiltration test will be required for each section of pipeline involving watertight joints. Although system layouts presently recommended are considered adequate, particular care should be exercised to provide a layout of subdrains that does not require water to travel appreciable distances through the base course due to impervious subgrade material or barriers. Pervious base courses with a minimum thickness of about 6 inches with provisions for drainage should be provided beneath pavements constructed on fine-grained subgrades and subject to perched water table conditions. Base courses containing more than 10 percent fines cannot be drained and remain saturated continuously.